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Mikolajewski et al.

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(54) **MATERIAL ALIGNER**

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(63) Continuation-in-part of application No. 17/190,545, filed on Mar. 3, 2021, now Pat. No. 11,268,223, and a continuation-in-part of application No. 16/984,815, filed on Aug. 4, 2020, now Pat. No. 10,988,880.

(51) **Int. Cl.**

D05B 35/00	(2006.01)
D05B 39/00	(2006.01)
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D05B 27/10	(2006.01)

(52) **U.S. Cl.**

CPC ***D05B 35/00*** (2013.01); ***D05B 27/10*** (2013.01); ***D05B 39/00*** (2013.01); ***D05B 57/30*** (2013.01)

(58) **Field of Classification Search**

CPC D05B 35/00; D05B 35/06; D05B 35/064; D05B 35/066; D05B 35/068; D05B 35/08; D05B 35/10; D05B 35/102–107; D05B 39/00; D05B 57/30; D05B 27/10–16

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,106,536 A		1/1938	Rubel	
2,546,527 A		3/1951	Smyth	
4,000,636 A	*	1/1977	Shubin	B21D 7/08 72/251

(Continued)

FOREIGN PATENT DOCUMENTS

EP	0383045 A1	8/1990
WO	2021204461 A1	10/2021

OTHER PUBLICATIONS

International Search Report for PCT/US2021/071093 dated Nov. 11, 2021.

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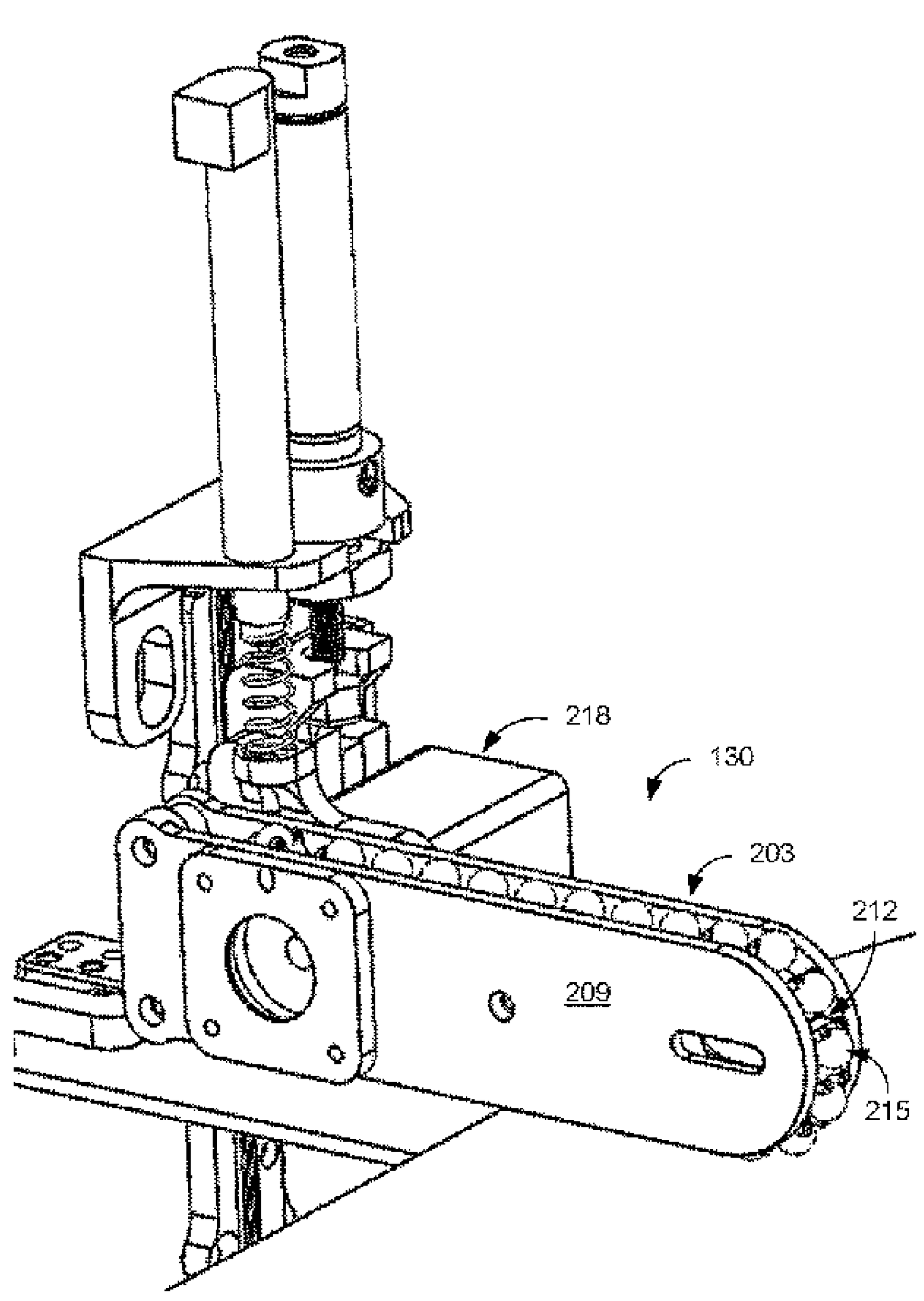
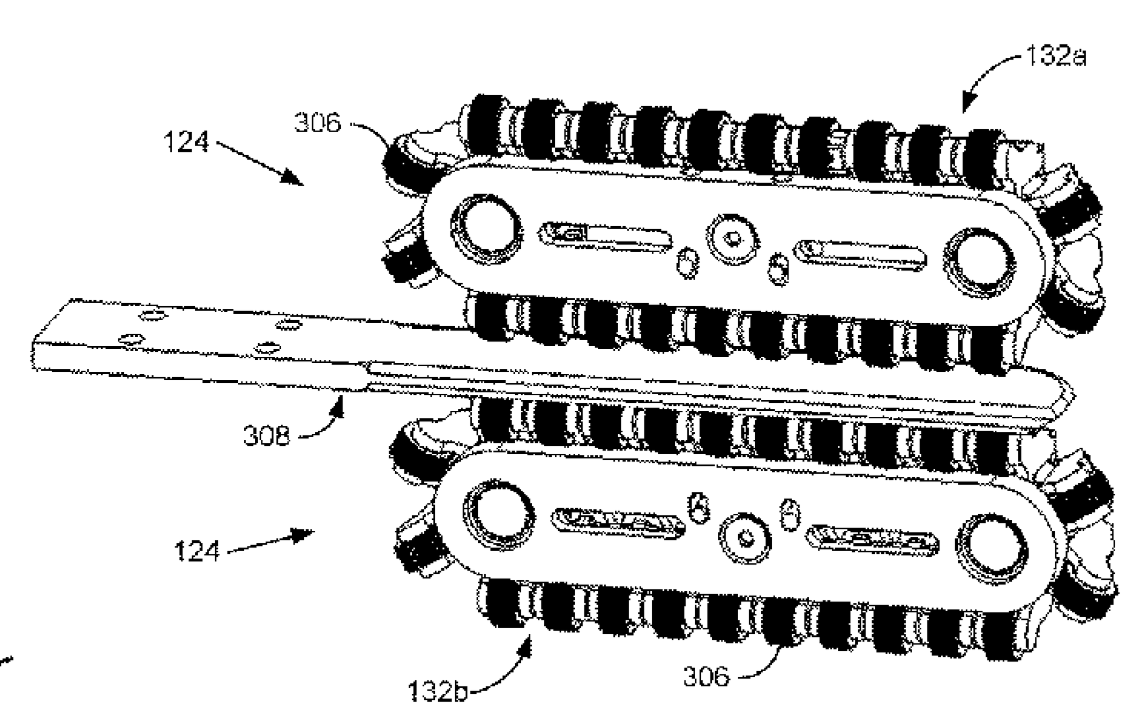
(57) **ABSTRACT**

Various examples are provided related to transporting and sewing material in, e.g., automation of sewing robots. An automated sewing process feed control system is disclosed in which a material aligner is utilized. An omni-chain material aligner can include a circular roller chain in which the rollers allow for a controlling force to be applied to a material. An omni-belt material aligner can include a belt with attached perpendicular rollers which allow feed control and active motorized steering control. The material aligner can control the pressure applied onto the material to facilitate control of feeding the material.

20 Claims, 10 Drawing Sheets





(56) **References Cited**

U.S. PATENT DOCUMENTS

4,191,118	A		3/1980	Blessing	
4,512,269	A	*	4/1985	Bowditch	D05B 33/00 112/311
4,714,036	A		12/1987	Raisin et al.	
4,813,364	A	*	3/1989	Boser	D05B 35/102 112/153
5,054,409	A		10/1991	Schips	
5,103,749	A	*	4/1992	Geisselmann	D05B 35/102 112/306
5,370,072	A		12/1994	Adamski, Jr.	
5,568,778	A		10/1996	Sahl	
5,806,449	A	*	9/1998	Schramayr	D05B 35/10 112/470.31
6,250,238	B1	*	6/2001	Resta	D05B 11/005 112/2.1
6,415,727	B1	*	7/2002	Burgess	D05B 29/02 112/152
8,695,519	B2		4/2014	Bearden	
8,919,269	B1		12/2014	Chen	

* cited by examiner

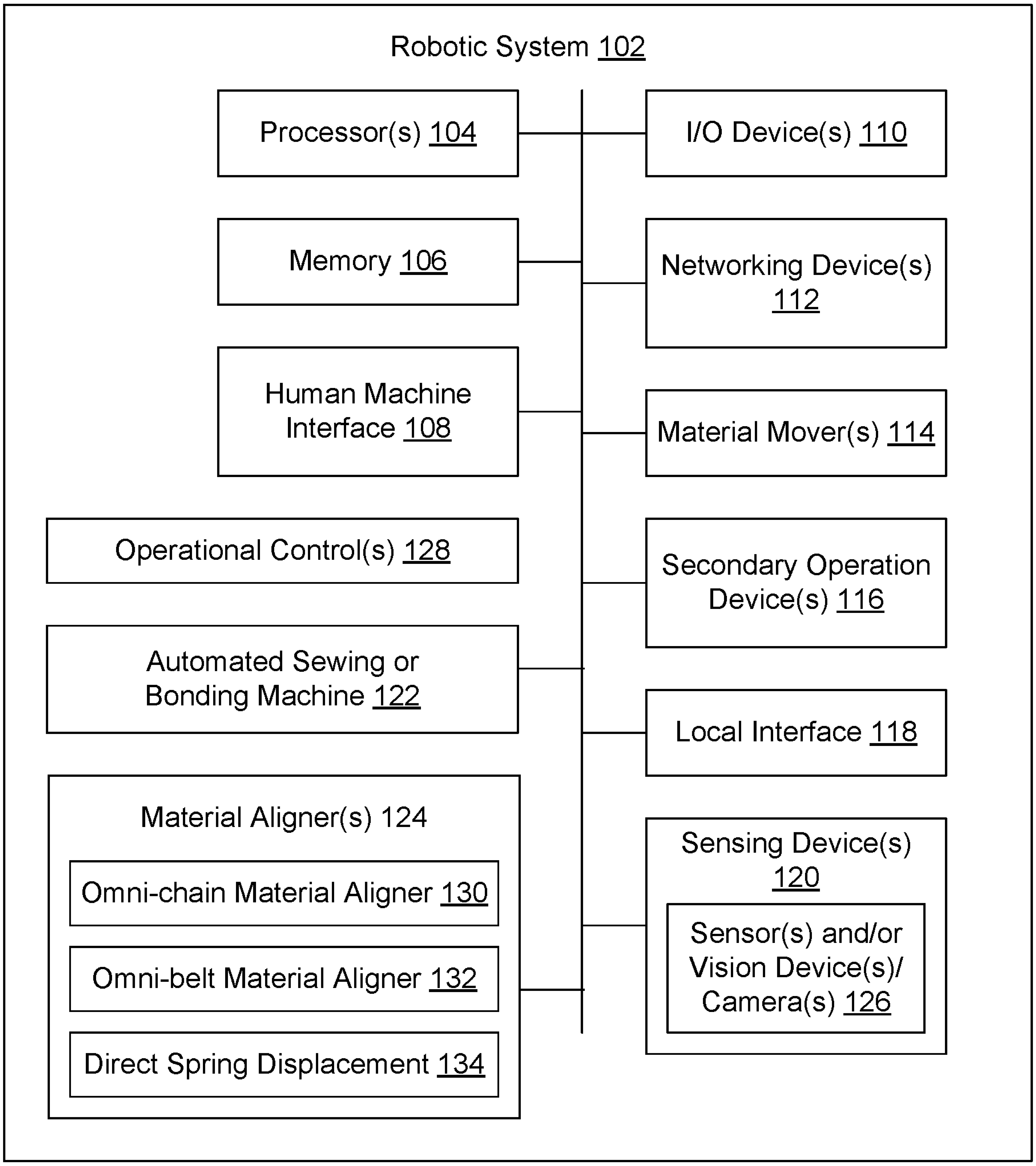

Robotic System 102
Processor(s) 104
I/O Device(s) 110
Memory 106
Networking Device(s) 112
Human Machine Interface 108
Material Mover(s) 114
Operational Control(s) 128
Secondary Operation Device(s) 116
Automated Sewing or Bonding Machine 122
Local Interface 118
Material Aligner(s) 124
Omni-chain Material Aligner 130
Omni-belt Material Aligner 132
Direct Spring Displacement 134
Sensing Device(s) 120
Sensor(s) and/or Vision Device(s)/ Camera(s) 126

FIG. 1

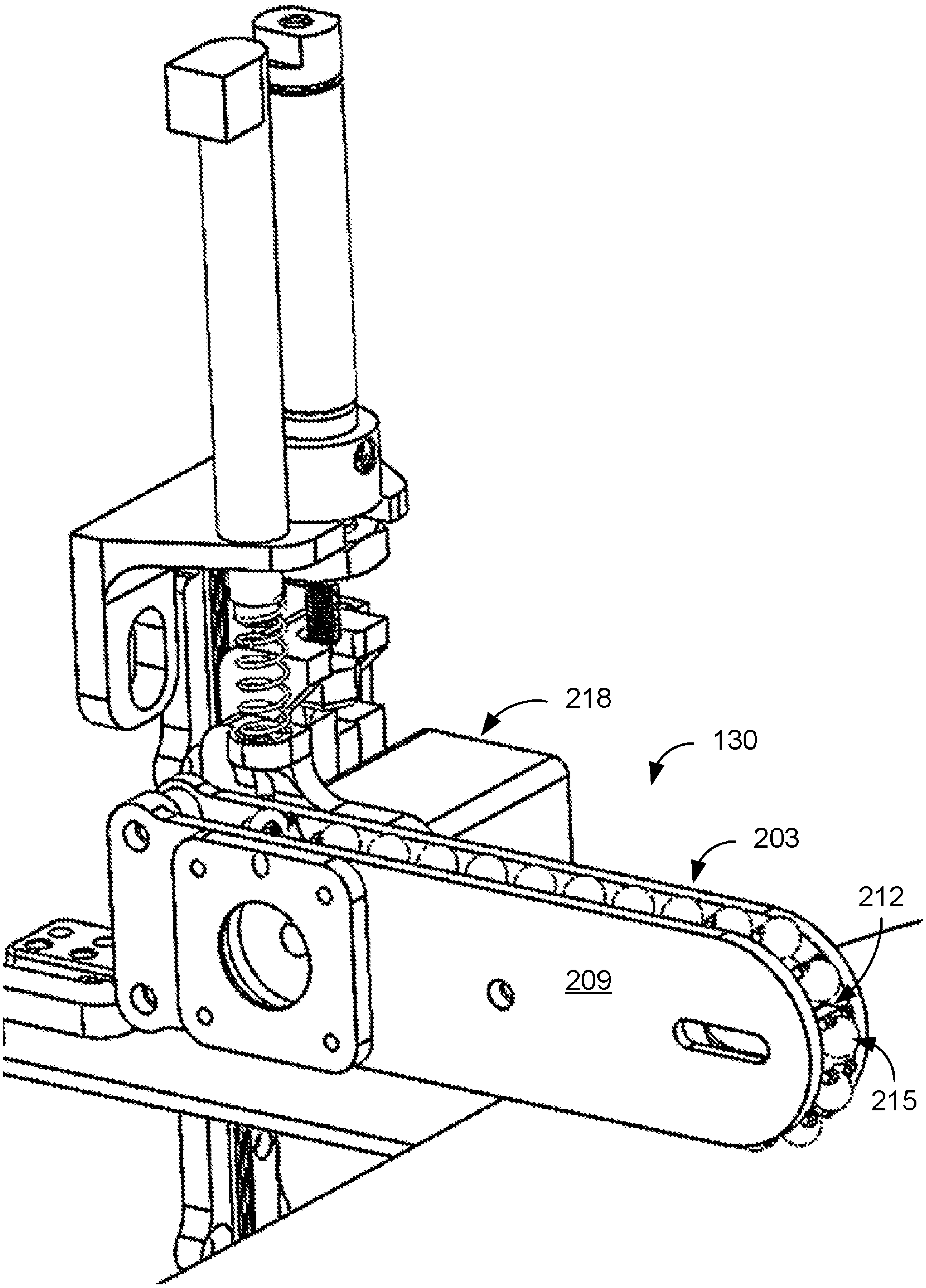


FIG. 2A

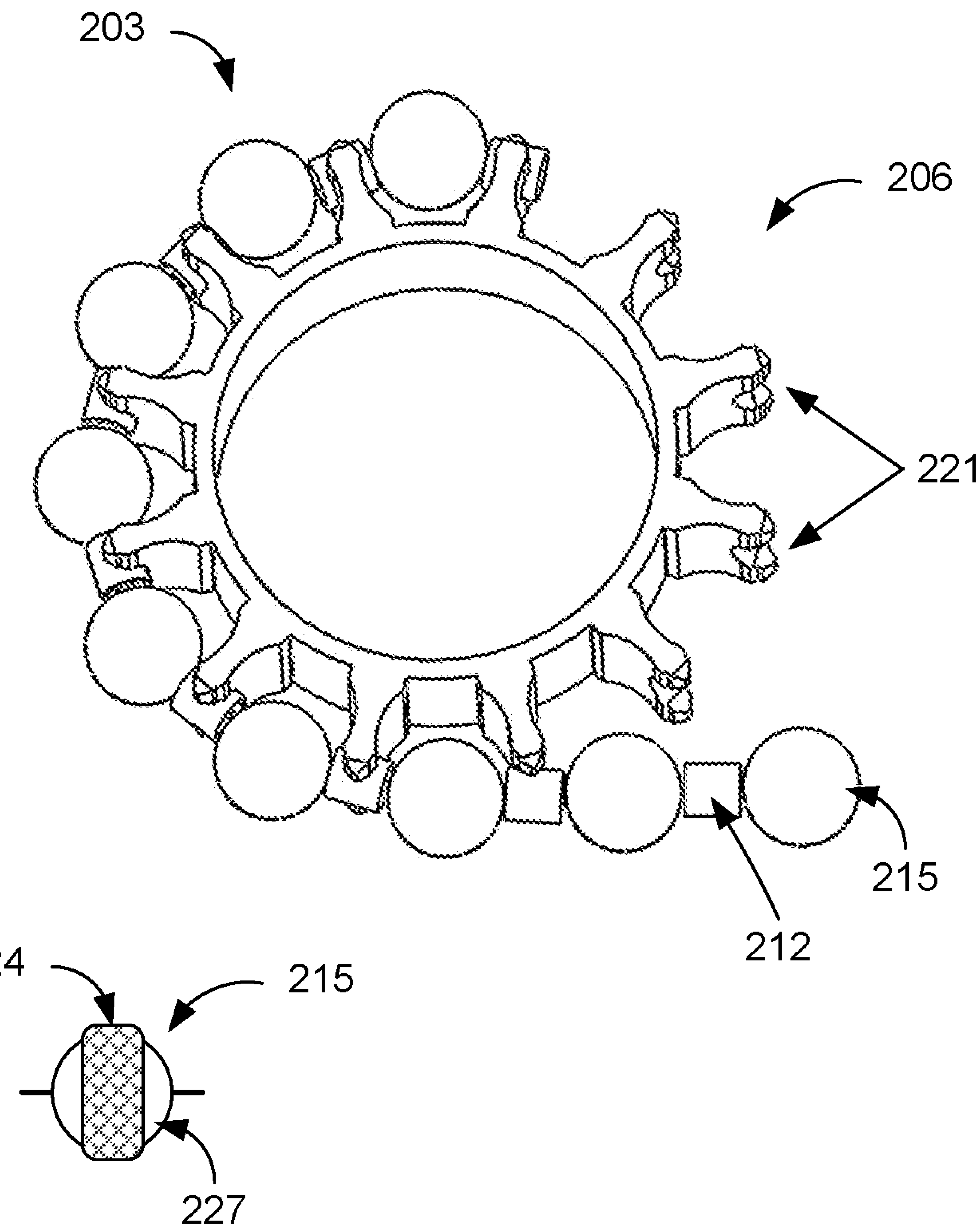


FIG. 2B

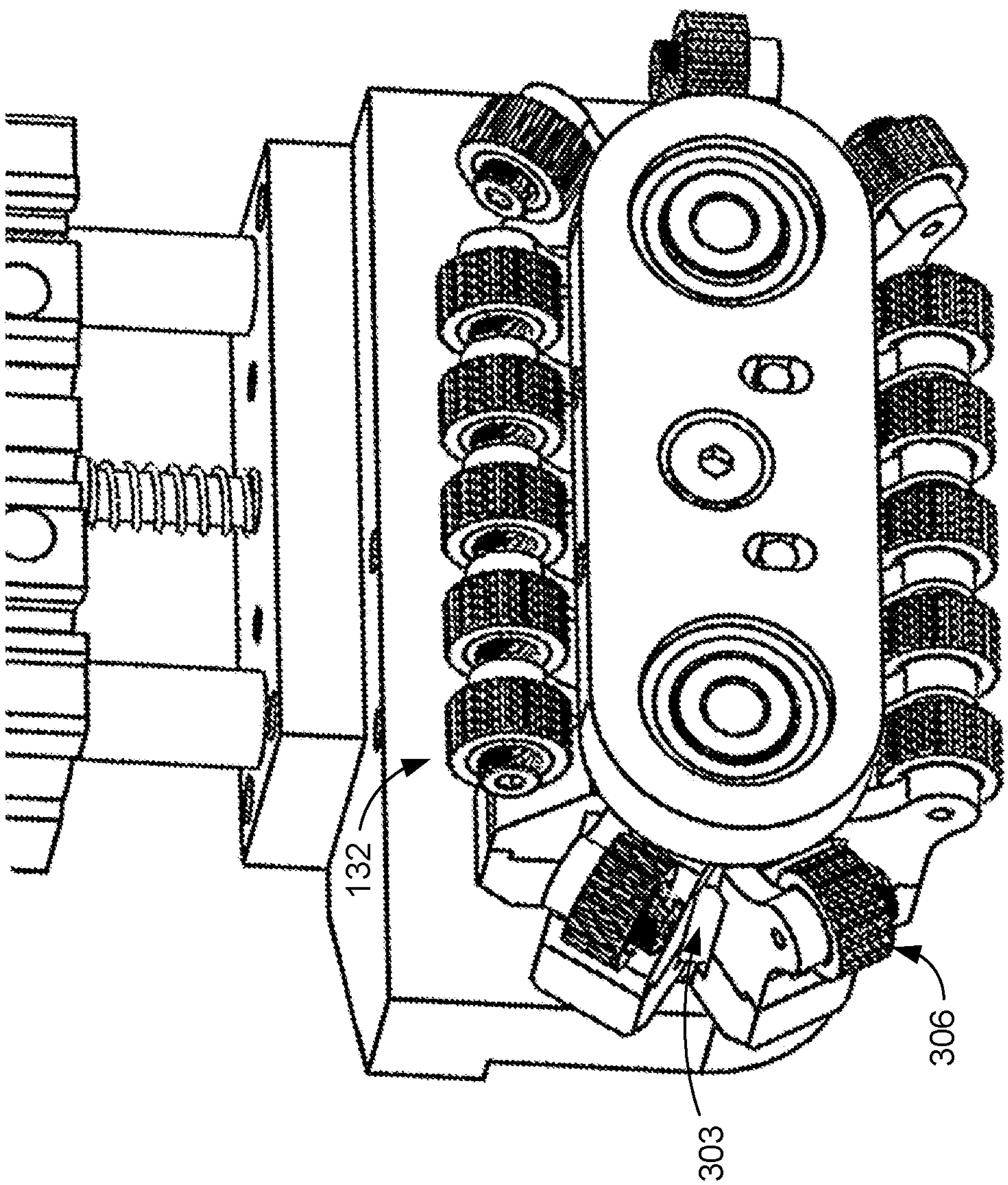


FIG. 3A

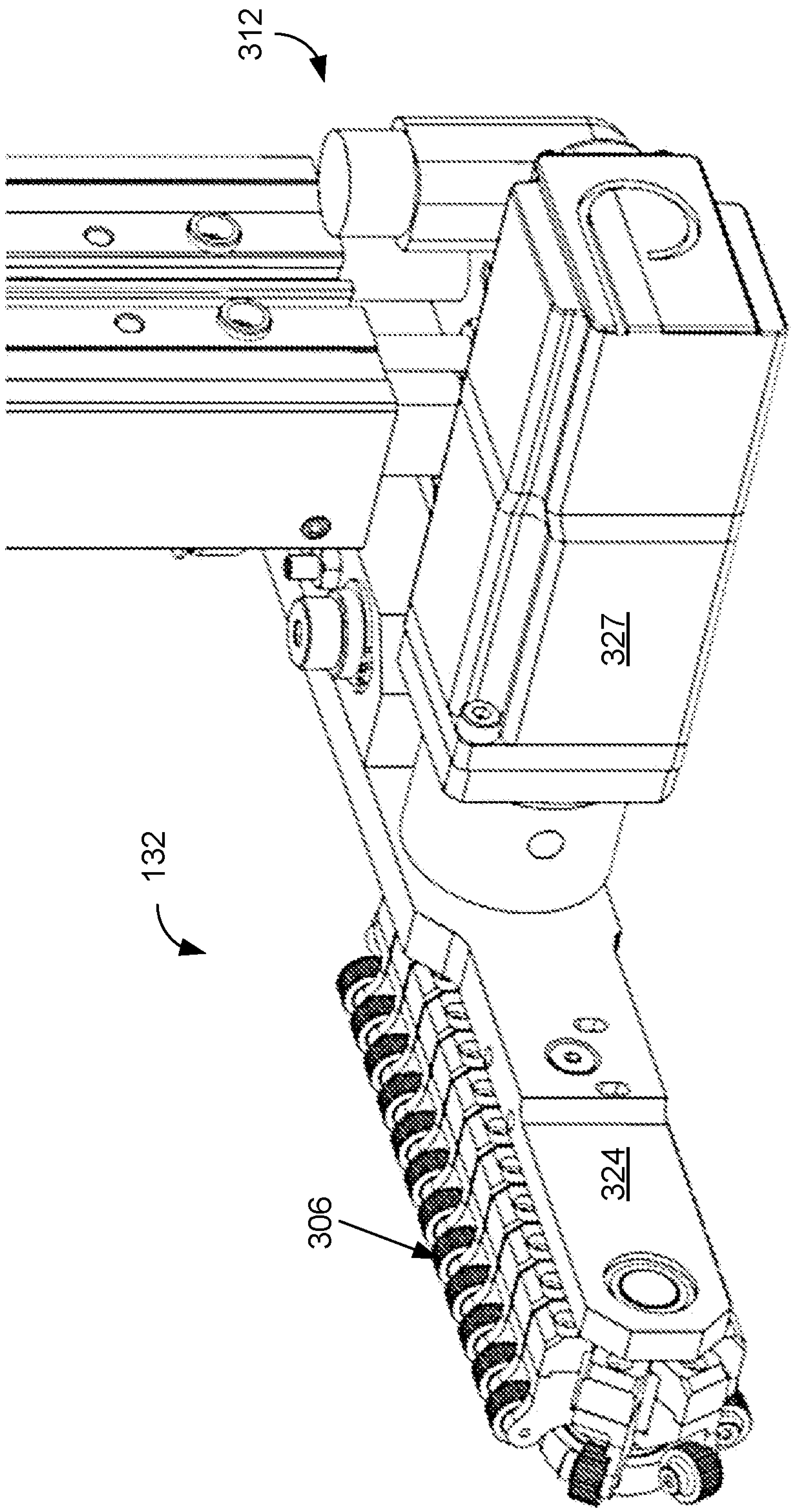


FIG. 3B

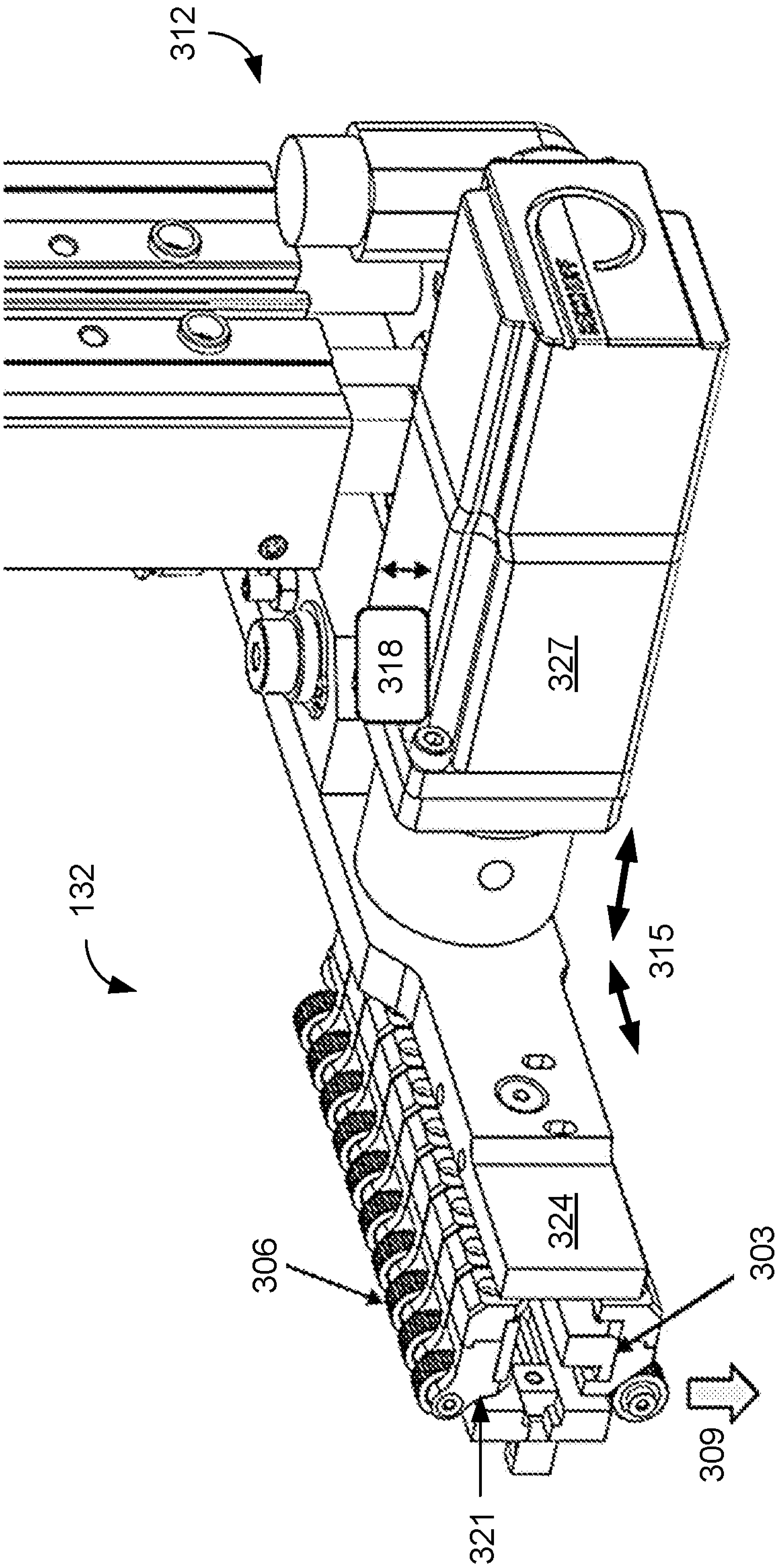


FIG. 3C

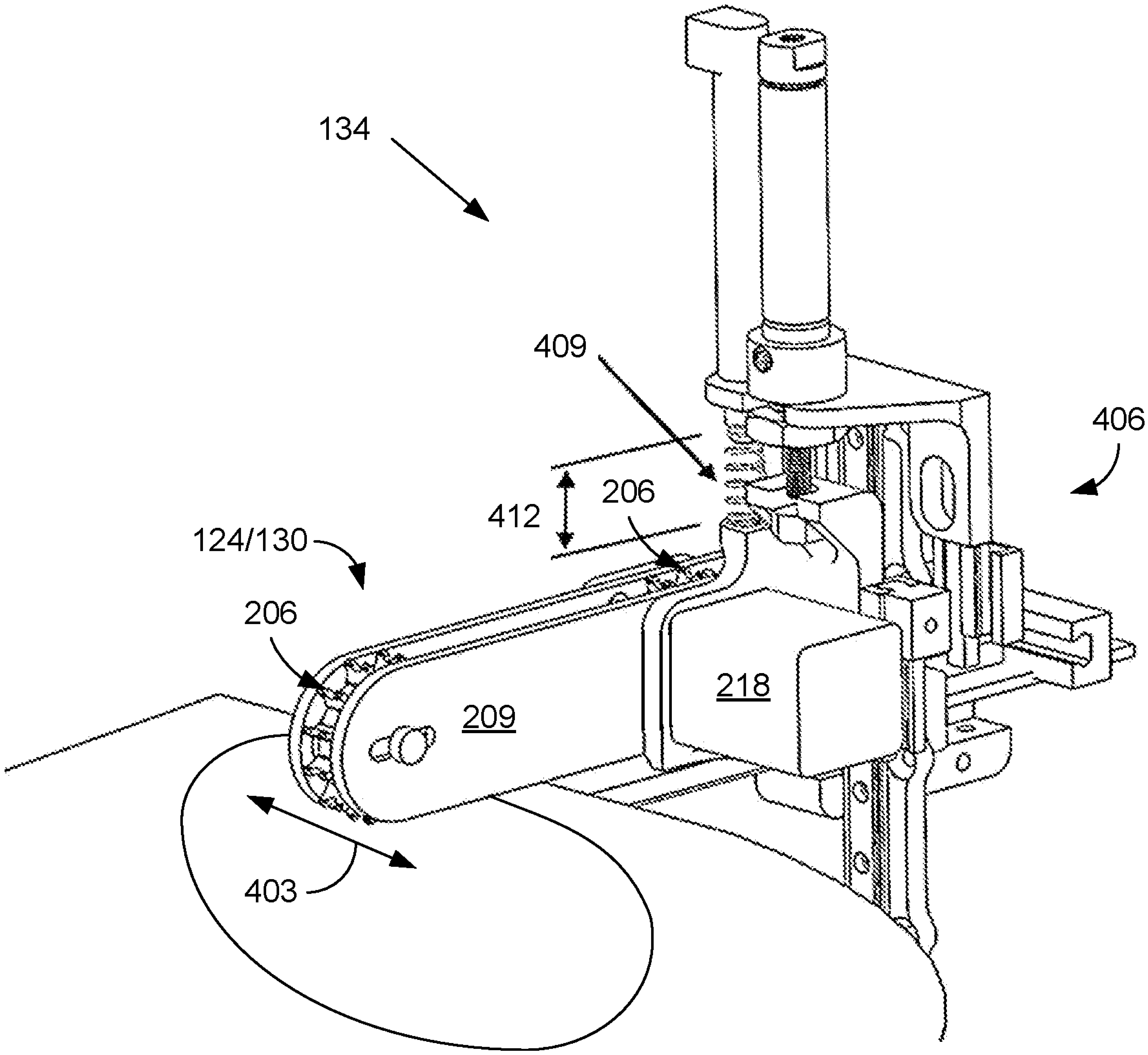


FIG. 4

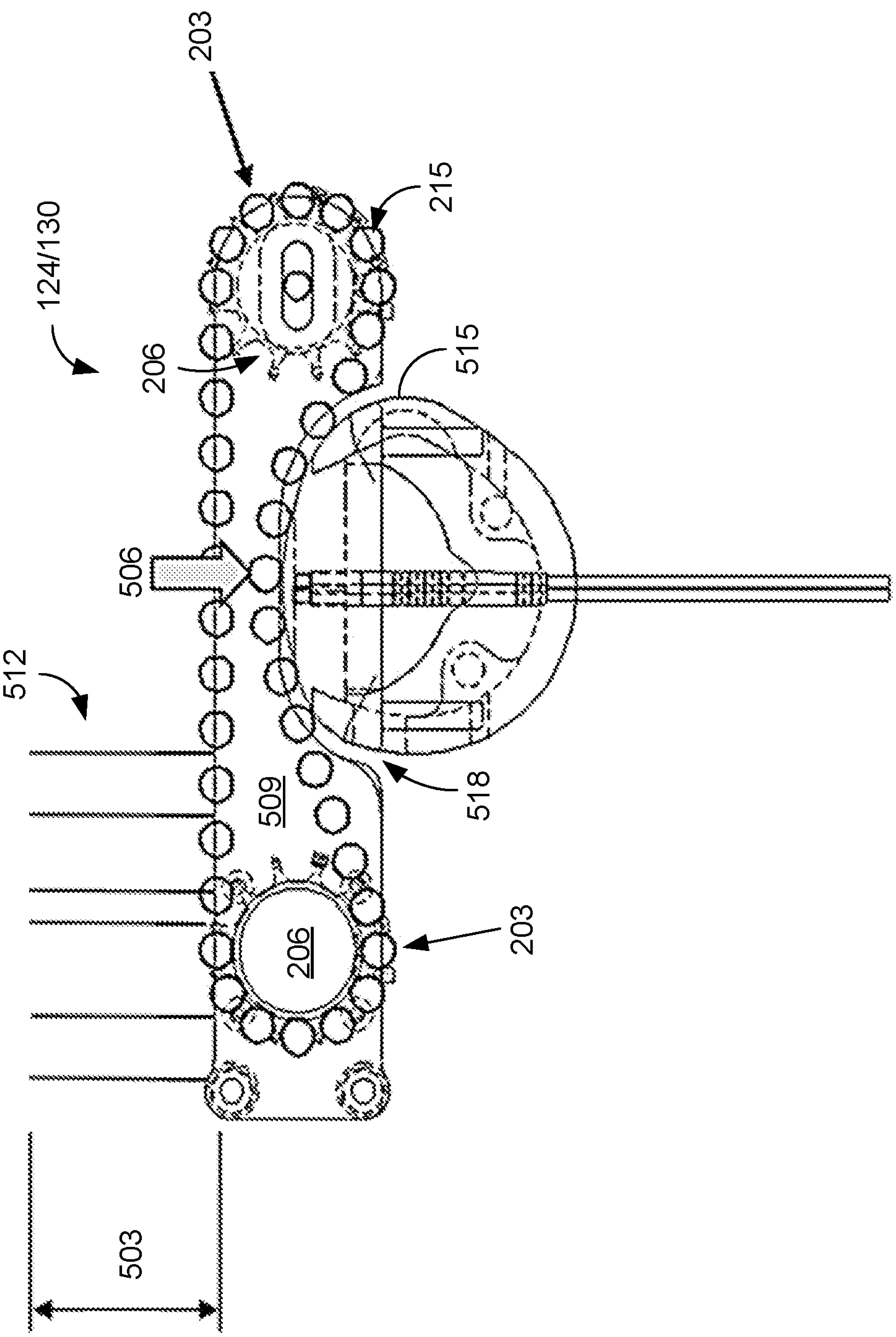


FIG. 5

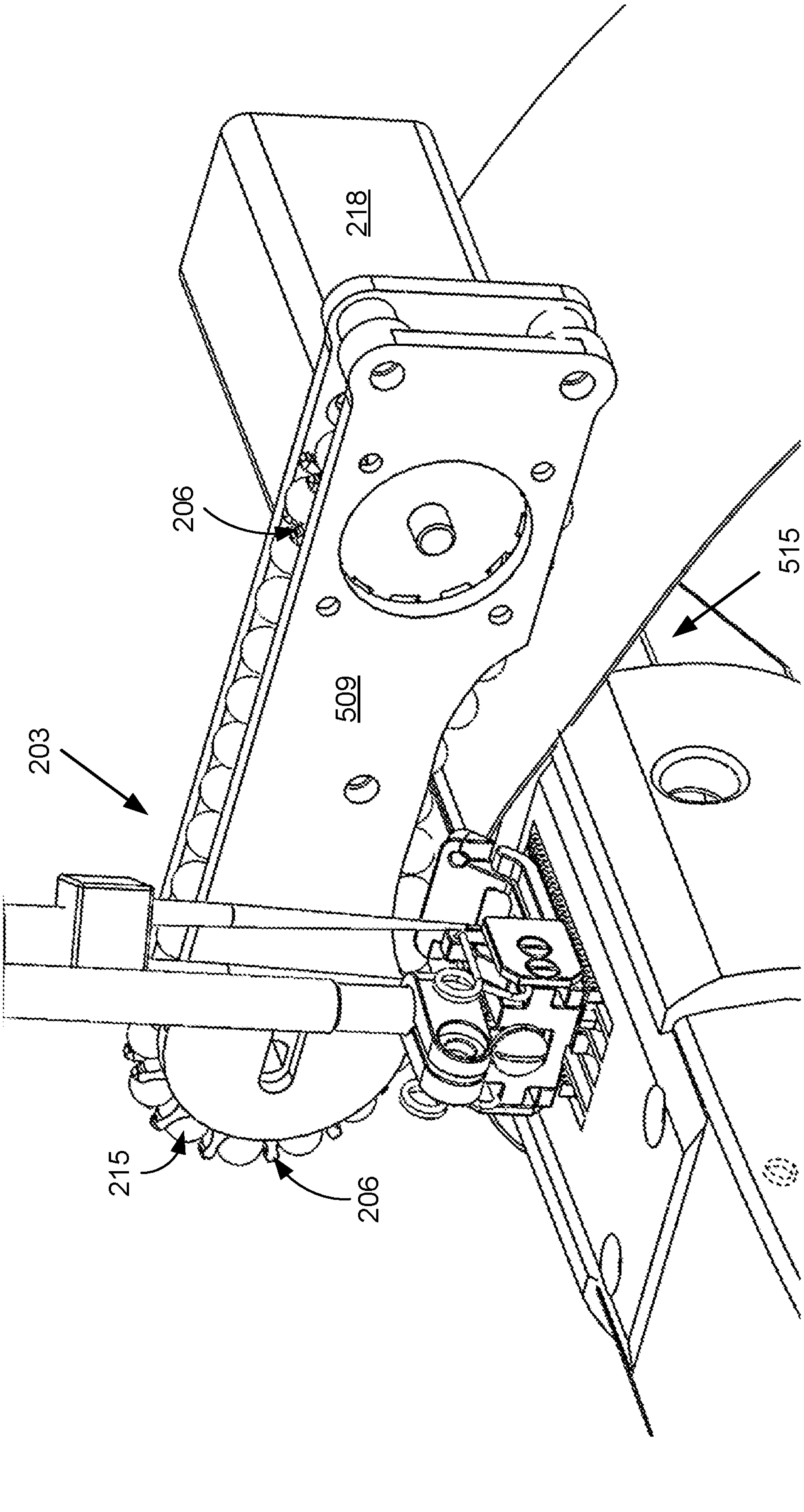


FIG. 6

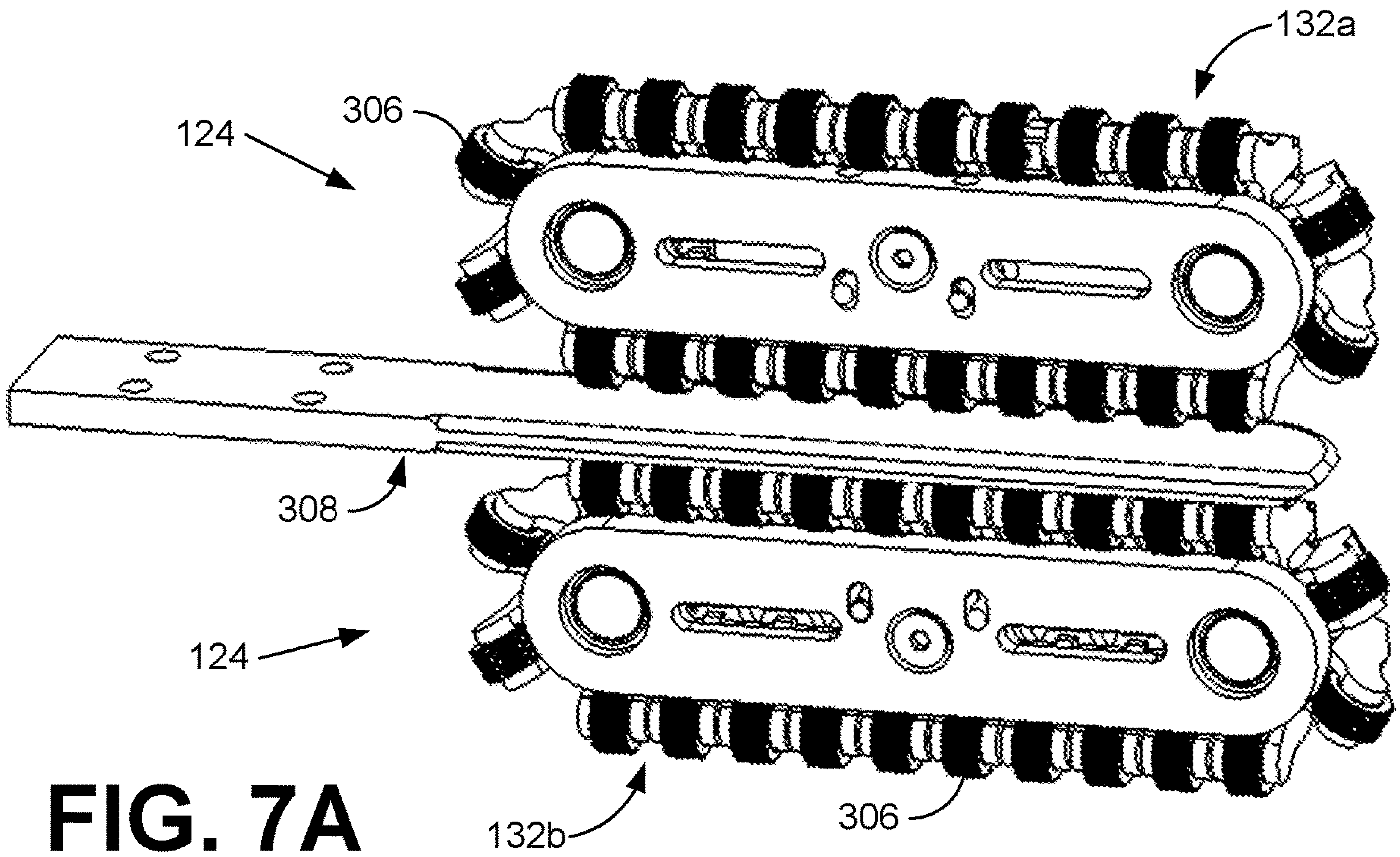


FIG. 7A

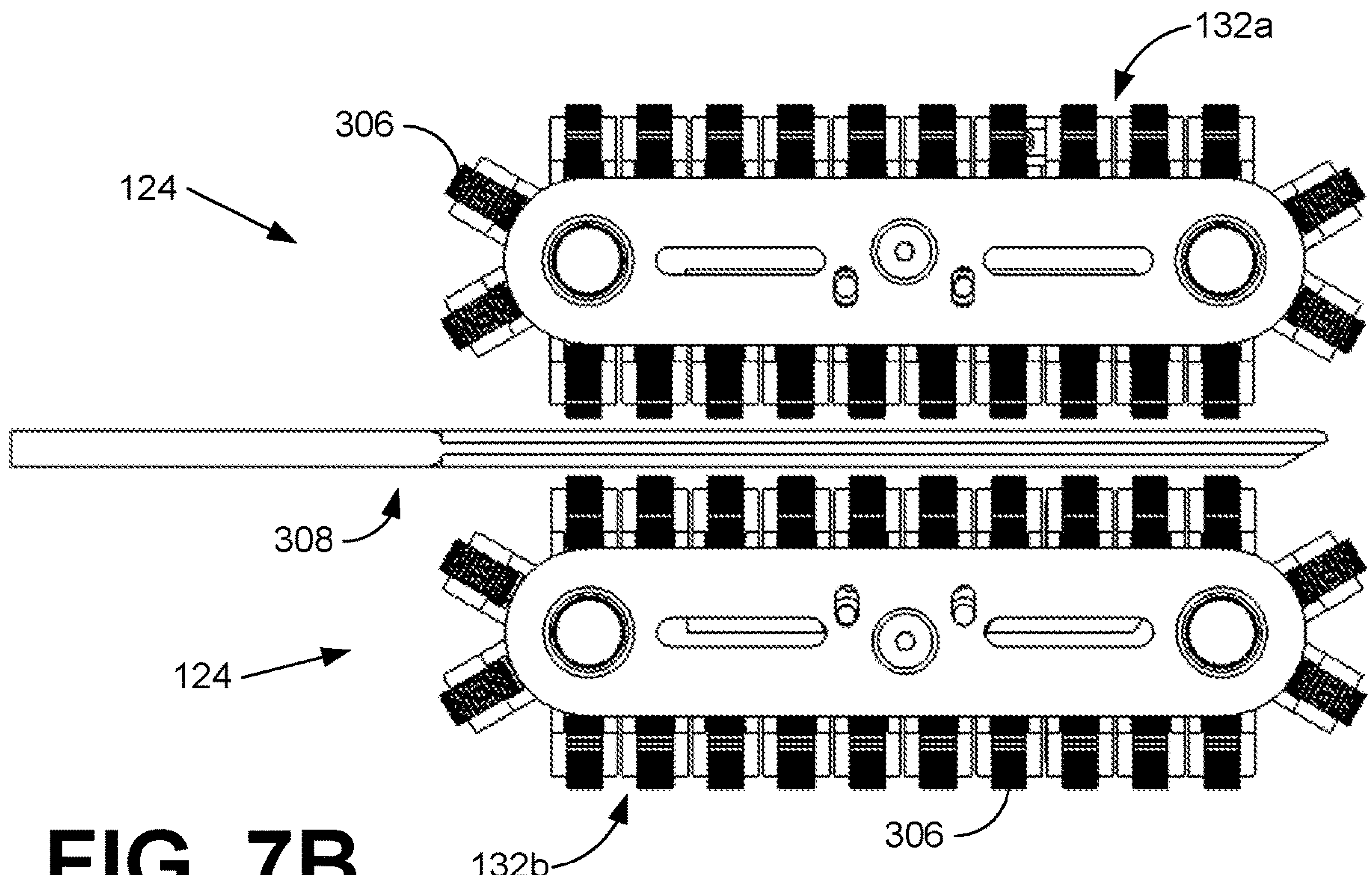


FIG. 7B

MATERIAL ALIGNER

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part application claiming priority to, and the benefit of, U.S. non-provisional application entitled "Material Aligner" having Ser. No. 16/984,815, filed Aug. 4, 2020, which is hereby incorporated by reference in its entirety. This application also claims priority to, and the benefit of, U.S. non-provisional application entitled "Garment Sleeve Attachment Systems and Methods" having Ser. No. 17/190,545, filed Mar. 3, 2021, which is hereby incorporated by reference in its entirety.

BACKGROUND

Maneuvering materials throughout an automated sewing process is a difficult task due to the flexibility and elasticity of materials. Materials may become misaligned during the process, requiring operator interaction. In order to maneuver material through an automated sewing process there needs to be an apparatus that can properly align the materials through the sewing machine without restricting the materials being fed through the sewing machine to reduce or eliminate the need for operator assistance.

The subject matter discussed in the background section should not be assumed to be prior art merely as a result of its mention in the background section. Similarly, a problem mentioned in the background section or associated with the subject matter of the background section should not be assumed to have been previously recognized in the prior art. The subject matter in the background section merely represents different approaches, which in and of themselves may also correspond to implementations of the claimed technology.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings illustrate various examples of systems, methods, and embodiments of various other aspects of the disclosure. Any person with ordinary skills in the art will appreciate that the illustrated element boundaries (e.g., boxes, groups of boxes, or other shapes) in the figures represent one example of the boundaries. It may be that in some examples one element may be designed as multiple elements or that multiple elements may be designed as one element. In some examples, an element shown as an internal component of one element may be implemented as an external component in another, and vice versa. Furthermore, elements may not be drawn to scale. Non-limiting and non-exhaustive descriptions are described with reference to the following drawings. The components in the figures are not necessarily to scale, emphasis instead being placed upon illustrating principles. Moreover, in the drawings, like reference numerals designate corresponding parts throughout the several views.

FIG. **1** illustrates an example of a robotic system, according to various embodiments of the present disclosure.

FIGS. **2**A and **2**B illustrate an example of an omni-chain material aligner, according to various embodiments of the present disclosure.

FIG. **3**A-**3**C illustrate examples of omni-belt material aligners, according to various embodiments of the present disclosure.

FIG. **4** illustrates an example of a direct spring displacement assembly, according to various embodiments of the present disclosure.

FIG. **5** illustrates an example of an omni-chain material aligner with chain displacement, according to various embodiments of the present disclosure.

FIG. **6** illustrates an example of an omni-chain material aligner following a seam, according to various embodiments of the present disclosure.

FIGS. **7**A and **7**B illustrate an example of a pair of material aligners positioned in an opposed arrangement, according to various embodiments of the present disclosure.

DETAILED DESCRIPTION

Disclosed herein are various examples related to manipulation or alignment of material for processing, e.g., in the automated production of sewn or bonded products. The present disclosure is generally related to systems, apparatuses, and methods for the manipulation or alignment of flexible or flimsy material such as, e.g., fabrics or thin films. For example, an apparatus such as a material aligner can be used in an automated sewing process feed control system for alignment of the material for processing. The material aligner can adapt to arbitrary seam shapes or edges during sewing or bonding of the material. Reference will now be made in detail to the description of the embodiments as illustrated in the drawings, wherein like reference numbers indicate like parts throughout the several views.

The words "comprising," "having," "containing," and "including," and other forms thereof, are intended to be equivalent in meaning and be open ended in that an item or items following any one of these words is not meant to be an exhaustive listing of such item or items, or meant to be limited to only the listed item or items.

It must also be noted that as used herein and in the appended claims, the singular forms "a," "an," and "the" include plural references unless the context clearly dictates otherwise. Although any systems and methods similar or equivalent to those described herein can be used in the practice or testing of embodiments of the present disclosure, the preferred systems and methods are now described.

Embodiments of the present disclosure will be described more fully hereinafter with reference to the accompanying drawings in which like numerals represent like elements throughout the several figures, and in which example embodiments are shown. Embodiments of the claims may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. The examples set forth herein are non-limiting examples and are merely examples among other possible examples.

Referring to FIG. **1**, shown is an example of a system that can be used for material manipulation and bonding (e.g., sewing, ultrasonic welding, thermal bonding, gluing or other bonding or joining technology). As illustrated in the example of FIG. **1**, the system can comprise a robotic system **102**, which can include a processor **104**, memory **106**, an interface such as, e.g., a human machine interface (HMI) **108**, I/O device(s) **110**, networking device(s) **112**, material mover(s) **114**, secondary operation device(s) **116**, a local interface **118**, sensing device(s) **120**, an automated sewing or bonding machine **122**, and material aligner(s) **124**. The sensing device(s) **120** can comprise one or more sensor and/or vision device/camera **126**. The automated sewing or bonding machine **122** includes a sewing machine with at least one sewing needle at the sewing head as will be discussed. In other embodiments, the automated sewing or bonding machine **122** can include a bonding or joining apparatus configured to bond the material together using, e.g., ultrasonic welding, thermal bonding, gluing or other bonding or joining technology appropriate for the material. The robotic system **102** can also include operational control(s) **128**, which can be executed by the robotic system **102** to implement manipulation and/or processing of materials. The material aligner(s) **124** can include, but are not limited to, omni-chain material aligner(s) **130** and omni-belt material aligner(s) **132**. Positioning of a material aligner **124** can be controlled by, e.g., direct spring displacement **134** or other appropriate positioning device or assembly.

The processor **104** can be configured to decode and execute any instructions received from one or more other electronic devices or servers. The processor can include one or more general-purpose processors (e.g., INTEL® or Advanced Micro Devices® (AMD) microprocessors) and/or one or more special purpose processors (e.g., digital signal processors or Xilinx® System on Chip (SOC) field programmable gate array (FPGA) processor). The processor **104** may be configured to execute one or more computer-readable program instructions, such as program instructions to carry out any of the functions described in this description.

The Memory **106** can include, but is not limited to, fixed (hard) drives, magnetic tape, floppy diskettes, optical disks, Compact Disc Read-Only Memories (CD-ROMs), and magneto-optical disks, semiconductor memories, such as ROMs, Random Access Memories (RAMs), Programmable Read-Only Memories (PROMs), Erasable PROMs (EPROMs), Electrically Erasable PROMs (EEPROMs), flash memory, magnetic or optical cards, or other type of media/machine-readable medium suitable for storing electronic instructions. The memory **106** can comprise one or more modules (e.g., operational control(s) **128**) that can be implemented as a program executable by processor(s) **104**.

The interface(s) or HMI **108** can accept inputs from users, provide outputs to the users or may perform both the actions. In one case, a user can interact with the interface(s) using one or more user-interactive objects and devices. The user-interactive objects and devices may comprise user input buttons, switches, knobs, levers, keys, trackballs, touchpads, cameras, microphones, motion sensors, heat sensors, inertial sensors, touch sensors, visual indications (e.g., indicator lights or meters), audio indications (e.g., bells, buzzers, etc.) or a combination of the above. Further, the interface(s) can either be implemented as a command line interface (CLI), a graphical user interface (GUI), a voice interface, or a web-based user-interface, at element **108**. The interface(s) can also include combinations of physical and/or electronic interfaces, which can be designed based upon the environmental setting or application.

The input/output devices or I/O devices **110** of the robotic system **102** can comprise components used to facilitate connections of the processor **104** to other devices such as, e.g., material mover(s) **114**, secondary operation device(s) **116**, sensing device(s) **120** and/or the automated sewing or bonding machine **122** and can comprise one or more serial, parallel, small system interface (SCSI), universal serial bus (USB), IEEE 1394 (i.e. Firewire™) connection elements or other appropriate connection elements.

The networking device(s) **112** of the robotic system **102** can comprise the various components used to transmit and/or receive data over a network. The networking device(s) **112** can include a device that can communicate both inputs and outputs, for instance, a modulator/demodulator (i.e. modem), a radio frequency (RF) or infrared (IR) transceiver, a telephonic interface, a bridge, a router, as well as a network card, etc.

The material mover(s) **114** of the robotic system **102** can facilitate material manipulation between operations. For example, the material mover(s) **114** may move, stack, or position the materials prior to the next operation. In some embodiments, the material mover(s) **114** may transport materials into a predetermined alignment or position prior to, during or after a cutting, sewing, or other operation.

The secondary operation device(s) **116** can include destacking device(s), stacking device(s), folding device(s), label manipulation device(s), and/or other device(s) that assist with the preparation, making and/or finishing of the sewn product.

The local interface **118** of the robotic system **102** can be, for example, but not limited to, one or more buses or other wired or wireless connections, as is known in the art. The local interface **118** can have additional elements, which are omitted for simplicity, such as controllers, buffers (caches), drivers, repeaters, and receivers, to enable communications. Further, the local interface **118** can include address, control, and/or data connections to enable appropriate communications among the components, at element **122**.

The sensing device(s) **120** of the robotic system **102** can facilitate detecting the position or movement of the product material(s) and inspecting the product material(s) for defects and/or discrepancies before, during or after a sewing or cutting operation or other process operation. Further, the sensing device(s) **120** can facilitate detecting markings on the product before cutting or sewing the material. A sensing device **120** can comprise, but is not limited to, one or more sensor and/or vision device/camera **126** such as, e.g., an RGB camera, an RGB-D camera, a near infrared (NIR) camera, stereoscopic camera, photometric stereo camera (single camera with multiple illumination options), time of flight camera, Internet protocol (IP) camera, light-field camera, monorail camera, multiplane camera, rapatronic camera, stereo camera, still camera, thermal imaging camera, acoustic camera, rangefinder camera, etc., at element **120**. The RGB-D camera is a digital camera that can provide color (RGB) and depth information for pixels in an image. The sensing device(s) **120** can also include one or more motion sensor(s), temperature sensor(s), humidity sensor(s), microphone(s), ultrasound device(s), radar or lidar device(s), RF receiver(s) and/or other environmental or electronic sensor(s). The sensing device(s) **120** can include an edge sensor or other feedback device such as, e.g., a laser or fiber optic sensor to locate the edge of the material being processed. The edge sensor or feedback device may provide data to determine appropriate adjustments needed to position the material on the correct processing path.

An automated sewing or bonding machine **122** is a sewing or bonding device or system that can include, e.g., a computerized sewing machine or a computerized bonding or joining apparatus (e.g., ultrasonic welding, thermal bonding, gluing or other bonding or joining technology). The automated sewing or bonding machine **122** can be configured to sew or otherwise bond or join (e.g., ultrasonic welding) a perimeter or other path on the material.

Material aligners **124** provide traction in one direction to control positioning of material in that direction, while concurrently allowing movement of the material in a perpendicular direction. The material aligner **124** can actively control the position of the material along an axis in the first direction. The material aligner **124** can also provide resistance to movement of the material perpendicular to that axis.

For example, as the material is pulled into the sewing or bonding machine, the resistance can provide tension in the material. The material aligners **124** can also allow movement of the material in directions at other angles than perpendicular to the first direction of active control. For instance, the material may be fed to the sewing machine **122** at an angle that is not perpendicular to the material aligner **124**. Examples of material aligners **124** include, e.g., omni-chain material aligners **130** and omni-belt material aligners **132**. The omni-chain material aligner **130** comprises a circular roller chain extending between two or more sprockets. The rollers of the circular roller chain provide traction in a first direction and rolling contact in a second perpendicular direction. The sprockets can be driven by a motor (e.g., a stepper motor) to perform active steering control of the material. Rolling contact and controlled roller pressure against the material allows for feed control (e.g. tension control) in the second direction and active steering control in the first direction during sewing or bonding. The omni-belt material aligner **132** comprises a belt (e.g., an indexed belt, chain, etc.) with attached perpendicular rollers, which allow feed control perpendicular to the length of the belt and active motorized steering control of the material being fed into the system along the length of the belt, while controlling applied roller pressure. Direct spring displacement **134** can be used to manage or control of the pressure applied by the material aligner **124** (e.g., the omni-chain material aligner **130** or the omni-belt material aligner **132**) onto the material to facilitate control of material feeding.

Material aligners **124** can also include, e.g., an omni-belt material aligner **132**, in which displacement can be controlled in order to control the applied pressure of the omni-belt on the material via torsion of the belt due to belt tension. Each offset-belt roller can contribute to the pressure applied along the full contact length of the material. Displacement of the omni-belt material aligner **132** can be controlled in order to control the applied pressure of the omni-belt on the material via the tension in the chain. Each omni-belt roller can contribute to the pressure applied along the full contact length of the material.

As shown in FIG. **1**, the robotic system **102** includes operational control(s) **128** which can control the robotic system **102**, as will be discussed. The operational control(s) **128** can include one or more process modules that can be executed in order to control operation of various components of the robotic system **102** such as the automated sewing or bonding machine **122** and/or the material aligner(s) **124**.

Functioning of the omni-chain material aligner **130** will now be discussed with reference to FIGS. **2**A and **2**B. One skilled in the art will appreciate that, for this and other processes and methods disclosed herein, the functions performed in the processes and methods may be implemented in differing order. Furthermore, the outlined steps and operations are provided as examples, and some of the steps and operations may be optional, combined into fewer steps and operations, or expanded into additional steps and operations without detracting from the essence of the disclosed embodiments.

Referring to FIGS. **2**A and **2**B, shown is an example of an omni-chain material aligner **130**, which includes a roller chain **203** extending between two sprockets **206** at opposite ends of a support arm **209**. FIG. **2**A displays an example of the omni-chain material aligner **130**, which enables rolling contact and controlled roller pressure against the material to allow for feed control. The circular roller chain **203** can comprise a series of spacers **212** which are located between the rollers **215** in the chain **203**. In some embodiments, the circular roller chain **203** can be free of spacers with a chain or linkage providing the separation between rollers **215**. FIG. **2**A shows an example of a portion of the roller chain **203** engaged with one of the sprockets **206**. The sprockets **206** can include projections (or "teeth") **221** distributed about the circumference of the sprocket **206** and extending radially outward to engage with the chain **203**.

In the example of FIG. **2**B, a distal end of the projections **221** is shaped to cradle and support the spacers **212** by extending along opposite sides of the spacers **212**. In some implementations, the projections can interface with the rollers **215** or the gap between the rollers **215** and the spacers **212**. In other embodiments, the sprocket **206** can be configured with continuous sides forming a channel in which the circular roller chain **203** rests, similar to a traditional pulley. In some cases, the circular roller chain **203** can be guided at one end by a channel or track in the support arm **209** and engaged with a single sprocket **206**, which can be driven by a motor **218**.

The rollers **215** can have a shape that allows for rotation with respect to (or about) an axis extending through the roller **215**. The rollers **215** are distributed along the length of the roller chain **203**. For example, the rollers **215** can be spherical (as shown in FIGS. **2**A and **2**B), ovular, cylindrical, or other appropriate geometry that facilitates rotation about the rotational axis. The rollers **215** can be attached to a cable, belt, chain, strap, etc. along the length of the circular roller chain **203** such that the rotational axis is substantially parallel with the attachment point. This allows the rollers **215** to provide a contact force to be applied to a material in a first direction and tension to be applied in a second perpendicular direction in a controlled manner through the movements of the circular roller chain **203**.

In some embodiments, the rollers **215** may be free spinning to not interfere or impede with a material moving parallel to the roller's rotation or provide a resistance to rotation in the direction of sewing (e.g., perpendicular to the rotational axis of the rollers **215** of the circular roller chain **203** on the sprockets **206**). Within the rollers **215** of the circular roller chain **203** and the spacers **212** can be a flexible cable running therethrough. In some embodiments, the flexible cable may be omitted, and the spacers **212** and rollers **215** may be interconnected in another manner such as being coupled together by various joints. For example, the spacers **212** can be flexibly connected with the adjacent rollers **215** by pins that allow the roller chain **203** to rotate about the sprockets **206**.

The rollers **215** in the circular roller chain **203** can be textured (e.g., comprising grooves, bumps, indents, etc.), or coated or wrapped with a coating or layer, to provide friction with the material. In some embodiments, the rollers **215** can comprise a low friction core (e.g., stainless steel) with a layer or coating (which can be textured or have other gripping properties) disposed on the roller surface that enhances the friction of the rollers **215**. The coating or layer can be formed in a band around the roller **215** to improve contact with the material as the roller rotates about the rotational axis. The coating or layer can have a ribbed or toothed profile to enhance contact. In some embodiments, the rollers **215** can comprise a hub or bearing with a contact element (e.g., a rubber tire or other contact material) secured around the hub. FIG. **2**B illustrates an example of a spherical roller **215** including a contact element **224** surrounding a hub **227**.

The sprockets **206** are connected at relative positions on the support arm **209** in order to support and provide a guide for the circular roller chain **203** to extend along the first direction while allowing the rollers **215** connected to the sprockets **206** to freely spin. The distal end of the projections of the sprockets **206** can include a recess that can mesh with the spacers **212** to hold the circular roller chain **203** in alignment on the sprocket **206**, while allowing the rollers **215** to still rotate when engaged. At least one sprocket **206** is driven by a motor **218** to perform active steering control, which may be used for edge alignment during an automated sewing process. In some embodiments, additional end effectors may be used in order to move the material through the omni-chain material aligner **130** in a motion perpendicular to the roller chain **203** while allowing the omni-chain material aligner **130** to provide the direction (either left or right) for the material.

Functioning of the omni-belt material aligner **132** will now be discussed with reference to FIG. **3**A. One skilled in the art will appreciate that, for this and other processes and methods disclosed herein, the functions performed in the processes and methods may be implemented in differing order. Furthermore, the outlined steps and operations are provided as examples, and some of the steps and operations may be optional, combined into fewer steps and operations, or expanded into additional steps and operations without detracting from the essence of the disclosed embodiments.

FIG. **3**A shows an example of an omni-belt material aligner **132**. The omni-belt material aligner **132** comprises a belt **303** with attached perpendicular rollers **306** which allow feed control and active motorized steering control of the material being fed into the system, while controlling applied roller pressure. In some embodiments, the belt **303** may be one of a plurality of types of belts such as, e.g., a timing belt, indexed belt, round belt, or flat belt. The belt **303** may also be a plurality of belts, or some combination of types of belts with the rollers in-between or outside the belts. In some embodiments, the belt may be replaced with one or more types of chains, such as linked member chains, bike chains, etc. or some combination of different types of chains.

Functioning of the omni-belt material aligner **132** will now be discussed with reference to FIGS. **3**B and **3**C. One skilled in the art will appreciate that, for this and other processes and methods disclosed herein, the functions performed in the processes and methods may be implemented in differing order. Furthermore, the outlined steps and operations are provided as examples, and some of the steps and operations may be optional, combined into fewer steps and operations, or expanded into additional steps and operations without detracting from the essence of the disclosed embodiments.

FIGS. **3**B and **3**C illustrate an example of the omni-belt material aligner **132**, which includes a belt **303** (e.g., a timing belt, flat belt, etc.) and a series of rollers **306** affixed to the belt **303** in an offset fashion along one side of the belt **303**. Force (arrow **309** of FIG. **3**C) can be applied to the material by the omni-belt material aligner **132** through the rollers **306**. Positioning the omni-belt material aligner **132** to press the rollers **306** against the material causes the belt **303** to twist, which acts as a spring to maintain the force on the material. Increasing the belt tension can increase the force produced by the twisting of the belt **303**. In some embodiments, each roller **306** can be spring or mass loaded individually or in groups to press against the material. In other embodiments, the rollers **306** can be affixed in a position over (or vertically offset from) the belt **303** such that pressure on a roller **306** does not impart a twist on the belt **303**.

Support and positioning of the omni-belt material aligner **132** can be provided by, e.g., the translation system **312** shown in FIGS. **3**B and **3**C or the translation system **406** shown in FIG. **4**. The translation system **312** can control up and down movement of the omni-belt material aligner **132** in in the Z direction (arrow **318**) and, in some implementations, planar movement in the XY directions (arrows **315**) as illustrated. The amount of pressure applied to the material can be controlled by the force applied to the rollers **306**, which are offset from the belt **303**, causing the belt **303** to twist.

FIG. **3**C includes a cross-sectional view of an end of the omni-belt material aligner **132**. The rollers **306** can be linked together on the belt **303** in order to provide rolling contact and control of the material. As shown, the series of rollers **306** can be connected to the belt **303** through, e.g., support frames or links **321** that can be detachably attached to the belt **303**. The rollers **306** are free to spin in one direction (e.g., perpendicular to the axial length of the support arm **324**) and are constrained in the direction along the axial length of the support arm **324**. Each roller **306** contributes pressure along the contact length of the material, which is accomplished via torsion of the belt **303** as previously described. The belt **303** can be a timing belt that includes teeth that can engage with a sprocket or gear driven by a motor **327** for active steering and control of the material.

Contact pressure can be applied to the material via the rollers through a variety of methods. For example, active control such as, e.g., pneumatic or electrical position control and passive control such as, e.g., direct spring displacement can be implemented to adjust or maintain the contact pressure to the material. Functioning of direct spring displacement will now be discussed with reference to FIG. **4**. One skilled in the art will appreciate that, for this and other processes and methods disclosed herein, the functions performed in the processes and methods may be implemented in differing order. Furthermore, the outlined steps and operations are provided as examples, and some of the steps and operations may be optional, combined into fewer steps and operations, or expanded into additional steps and operations without detracting from the essence of the disclosed embodiments.

FIG. **4** illustrates an example of a direct spring displacement assembly **134** that can be used for controlling the force applied to the material through the material aligner **124** with direct spring displacement **134**. In the example of FIG. **4**, an omni-chain material aligner **130** (without the circular roller chain **203**) is shown for illustration. Control of the force applied by the material aligner **124** onto the material affects the contact that the material experiences. The amount of contact pressure that the material experiences can affect the tension of the material as it is pulled by the sewing machine perpendicularly to the material aligner **124** (see arrow **403**).

As illustrated in FIG. **4**, the assembly can include a translation system **406** that can support and position the material aligner **124**. The translation system **406** shown in FIG. **4** can produce XYZ motion in which the XY motion is planar motion and the Z motion is up and down motion. The translation system can be controlled (e.g., through pistons, cylinders, linear motors, etc.) to position the material aligner **124** on the material for processing. The material aligner **124** can be pressed against the material with the aid of a spring **409**, which may be set or controlled to apply a desired force onto the material being controlled. This embodiment would have the advantage of being independent from material height since the force is no longer depended on the displacement **412** of the spring **409**. The force applied by the spring

409 may be adjusted using, e.g., a screw-type linear motor which can vary compression of the spring **409** against the material aligner **124**. In some embodiments, a powered device such as, e.g., a pneumatic piston, electric solenoid or other appropriate mechanism to apply a controlled force which may be used as a substitute for the spring **409** to press the material aligner **124** down on the material.

Functioning of the chain tension displacement for a material aligner **124** will now be discussed with reference to FIG. **5**. One skilled in the art will appreciate that, for this and other processes and methods disclosed herein, the functions performed in the processes and methods may be implemented in differing order. Furthermore, the outlined steps and operations are provided as examples, and some of the steps and operations may be optional, combined into fewer steps and operations, or expanded into additional steps and operations without detracting from the essence of the disclosed embodiments.

FIG. **5** is a cross-sectional view illustrating an example of chain displacement in a material aligner **124** (e.g., an omni-chain material aligner **130**) to account for shape variations. In the embodiment of FIG. **5**, the omni-chain material aligner **130** comprises a circular roller chain **203** extending between two sprockets **206** mounted to a support arm **609**. The rollers **215** of the circular roller chain **203** provide traction in one direction in line with the circular roller chain **203** and rolling contact in a perpendicular direction. The sprockets **206** can be driven by a motor to perform active steering control of the material. The support arm **609** can be shaped with a curved recess **518** along the lower edge to allow the roller chain **203** extending across the opening of the recess to flex upward. For example, the work surface **621** can be a curved surface that aids in the sewing a seam by the automated sewing or bonding machine **122**. With the material positioned on the curved work surface **621**, the circular roller chain **203** can be pressed onto the material to provide the active steering control. Each roller **215** on the chain **203** contributes pressure along the contact length of the material.

Support and positioning of the omni-chain material aligner **130** can be provided by, e.g., a translation system **612** that can produce Z motion, planar XY motion, or a combination of both. Vertical displacement (Z motion) of the material aligner is represented by arrow **603**. The circular roller chain **203** can be positioned on the material by lowering the omni-chain material aligner **130** onto the material on the curved work surface **615**. As the omni-chain material aligner **130** is lowered, the pressure (arrow **606**) applied to the material by the circular roller chain **203** can vary as the position of the material aligner is changed. The embodiment of FIG. **5** provides additional flexibility of the chain to provide the ability to control material over curved or flexed surfaces. The slack in the chain can be adjusted to provide the appropriate flexibility for a curved surface and provide control of a material over a flat surface. In some implementations, the chain slack can be controlled by varying the distance between the sprockets **206** by repositioning one or more of the sprockets **206**.

Operation of a material aligner **124** will now be discussed with reference to FIG. **6**. One skilled in the art will appreciate that, for this and other processes and methods disclosed herein, the functions performed in the processes and methods may be implemented in differing order. Furthermore, the outlined steps and operations are provided as examples, and some of the steps and operations may be optional, combined into fewer steps and operations, or expanded into additional steps and operations without detracting from the essence of the disclosed embodiments.

FIG. **6** shows an example of the omni-chain material aligner **130** of FIG. **5** following a seam that is being fed into a sewing machine **122**. While this example discusses operation of the omni-chain material aligner **130**, it is also applicable to the omni-belt material aligner **132**. As the seam is sewn by the sewing needle, the material can be pulled through the sewing machine **122** by a feed mechanism. In some embodiments, movement of the material through the sewing machine **122** may be provided by an end effector, actuator, or by some other material mover **114**. With the material laying on the work surface **515** (curved or otherwise), the circular roller chain **203** can be positioned on the material to provide a desired force against the material. Contact pressure can be applied to the material via the rollers **215**.

Movement of the circular roller chain **203** on the sprockets **206** can reposition the material on the work surface during the sewing process. By rotating the circular roller chain, the material can be made to change its angle with respect to the sewing machine feed direction and or shift along the first direction extending along the material aligner **124**. Shifting the material side-to-side can change the angle that the material is supplied to the sewing needle, which allows the seam to be sewn along a curved or nonlinear path. Adjustment of the material position can be based upon a tracking feature (e.g., the seam or other optically or mechanically detectable feature of the material) that can be detected by the sensing device(s) **120** of the robotic system **102** (FIG. **1**). One or more material aligners **124** can be utilized to facilitate following the tracking feature as it is related to stitching or adhering another material to the surface of the material(s). For example, for materials already joined together with a seam, laying open and flat on the work surface **515** (with the seam facing the surface **515** or facing away from the surface **515**), the sewing path can be controlled by tracking the seam in the material.

In some implementations, two or more material aligners **124** can be arranged to control alignment of different pieces of material for bonding, attachment, or other operations. Referring to FIGS. **7**A and **7**B, shown is an example of a pair of material aligners **124** (e.g., omni-chain material aligners **130** or omni-belt material aligners **132**) positioned in an opposed configuration. This arrangement of opposing material aligners **124** can be used to control positioning of two pieces of material as they are being fed into a system for processing. For example, the material aligners **124** can maintain proper alignment of the material being fed to an automated sewing or bonding machine **122** for joining together or attachment to another component through, e.g., sewing, ultrasonic welding, thermal bonding, gluing or other bonding or joining technology. FIGS. **7**A and **7**B are perspective and side views illustrating top and bottom omni-belt material aligners **132***a* and **132***b* on opposite sides of a ply separator **708**.

The omni-chain material aligners **130** can comprise a circular roller chain **203** extending between two or more sprockets **206** (FIG. **2**A). The rollers **215** of the circular roller chain **203** provide traction in a first direction and rolling contact in a second perpendicular direction. Rolling contact and controlled roller pressure against the material allows for feed control (e.g. tension control) in the second direction and active steering control in the first direction during sewing or bonding. The sprockets can be driven by a motor (e.g., a servomotor or stepper motor) to perform active steering control of the material.

The omni-belt material aligners **132** can include rollers **306** linked together on a belt **303** to provide rolling contact and control of the material. As shown in FIG. **3**C, the series of rollers **306** can be connected to the belt **303** through, e.g., support frames or links **321** that can be detachably attached to the belt **303**. The rollers **306** are free to spin in one direction (e.g., perpendicular to the axial length of the support arm **324**) and are constrained in the direction along the axial length of the support arm **324**. Each roller **306** contributes pressure along the contact length of the material, which is accomplished via torsion of the belt **303** as previously described. The belt **303** can be driven by a motor (e.g., a servomotor or stepper motor) to perform active steering control of the material.

The material aligners **124** can maintain proper alignment of pieces of material being fed to a bonding or joining apparatus for sewing or bonding the material together or to another item. Alignment of the material can be accomplished using the bottom and top material aligners **124** (**132***b* and **132***a*, respectively). In some embodiments, a ply separator **308** can be located between the top and bottom material aligners **132***a* and **132***b*. The ply separator **308** can be, e.g., a plate that can separate first and second layers of material allowing the top and bottom material aligners **132***a* and **132***b* to act on a single layer of material while reducing its effects on the other layer of material. The ply separator **308** can comprise two planar or contoured surfaces. For example, a first ply or piece of material can be fed between the bottom material aligner **132***b* and a lower surface of the ply separator **308** and a second ply or piece of material can be fed the top material aligner **132***a* and an upper surface of the ply separator **308**. The material aligners **124** can provide traction in one direction to control positioning of the material in that direction, while concurrently allowing movement of the material in a perpendicular direction. For example, the material aligners **132***a* and **132***b* can comprise a series of rollers that operate as idlers in the feed direction of the sewing or bonding machine **122**, while providing controlled movement of the material.

In the example of FIGS. **7**A and **7**B, movement of the rollers about the bottom material aligner **132***b* can shift the first piece of material from side-to-side on the bottom surface of the ply separator **308** and the top material aligner **132***a* can shift the second piece of material from side-to-side on the top surface of the ply separator **308** to keep the pieces of material aligned or in the proper position during the joining (e.g., sewing or bonding) process as the pieces of material are feed into the joining head. For example, edges of two pieces of material can be aligned using the material aligners **132***a* and **132***b* based upon signals from edge or other sensors.

In some cases, the material aligners **132***a* and/or **132***b* can be repositioned to allow the material to be loaded into position between the material aligner **132***a* or **132***b* and the ply separator **308**. For instance, an actuator can retract the material aligner **132***a* or **132***b* away from the ply separator **308** to loading of the material and return the material aligner to secure or position the material during processing. Positioning of the material aligners **132***a* and **132***b* against the material or away from the ply separator **308** can be provided by pneumatic, servo or other appropriate actuator. The actuators can also adjust pressure applied through the rollers of the material aligners. The supports or translation systems for the material aligners are not shown for illustration purposes.

In FIGS. **7**A and **7**B, the top and bottom material aligners **132***a* and **132***b* are positioned with their lengths substantially aligned. As illustrated, the material aligners **132***a* and **132***b* are positioned in a common plane with the rollers **306** on the bottom side of the top material aligner **132***a* adjacent to the rollers **306** on the top side of the bottom material aligner **132***b*. The material aligners **132***a* and **132***b* can be substantially perpendicular to the surface of the ply separator **308** (as illustrated in FIGS. **7**A and **7**B) or can be positioned at an angle with respect to the surface of the ply separator **308**. For example, one or both of the material aligners **132***a* and/or **132***b* can be tipped (e.g., either towards and/or away from the sewing or bonding machine **122**) for access or other purposes. In addition, the material aligners **132***a* and **132***b* can be offset or staggered from each other. For instance, top material aligner **132***a* can be positioned at one edge of the ply separator **308** (e.g., closer to the sewing or bonding machine **122**) and the bottom material aligner **132***b* can be positioned at the other edge of the ply separator **308** (e.g., further away from the sewing or bonding machine **122**).

In some implementations, a ply separator **308** may not be included between the top and bottom material aligners **132***a* and **132***b*. The first and second pieces of material can be held between the top and bottom material aligners **132***a* and **132***b* with the material plies in contact with each other. The pieces of material can slide against each other allowing the top and bottom material aligners **132***a* and **132***b* to independently adjust their positions. Edge sensors can be used to monitor the positioning and alignment of the material. For example, the edge sensors can include a fiber optic array, vision device, mechanical sensor, or other appropriate sensor. The edge sensors can monitor the locations of the material edges, which can be used to control the material aligners **132***a* and **132***b* to maintain the edges in the proper position.

In some embodiments, a guide can partially surround a material aligner **124** to guide the material into or through the material aligner **124**. For example, a guide can be provided to assist in loading a piece of material between one of the material aligners **132***a* or **132***b* and the ply separator **308**. As a piece of material is provided at one end of the material aligner over the guide, the material aligner **132***a* or **132***b* can engage with the material to pull it over the guide and between the ply separator **308** and the material aligner. The material aligner **132***a* or **132***b* can position the piece of material for processing. The guide can be configured to feed the material between the material aligner and ply separator to avoid or prevent bunching during processing.

It should be emphasized that the above-described embodiments of the present disclosure are merely possible examples of implementations set forth for a clear understanding of the principles of the disclosure. Many variations and modifications may be made to the above-described embodiment(s) without departing substantially from the spirit and principles of the disclosure. All such modifications and variations are intended to be included herein within the scope of this disclosure and protected by the following claims.

The term “substantially” is meant to permit deviations from the descriptive term that don’t negatively impact the intended purpose. Descriptive terms are implicitly understood to be modified by the word substantially, even if the term is not explicitly modified by the word substantially.

It should be noted that ratios, concentrations, amounts, and other numerical data may be expressed herein in a range format. It is to be understood that such a range format is used for convenience and brevity, and thus, should be interpreted in a flexible manner to include not only the numerical values explicitly recited as the limits of the range, but also to include all the individual numerical values or sub-ranges encompassed within that range as if each numerical value and sub-range is explicitly recited. To illustrate, a concentration range of "about 0.1% to about 5%" should be interpreted to include not only the explicitly recited concentration of about 0.1 wt % to about 5 wt %, but also include individual concentrations (e.g., 1%, 2%, 3%, and 4%) and the sub-ranges (e.g., 0.5%, 1.1%, 2.2%, 3.3%, and 4.4%) within the indicated range. The term "about" can include traditional rounding according to significant figures of numerical values. In addition, the phrase "about 'x' to 'y'" includes "about 'x' to about 'y'".

Therefore, at least the following is claimed:

1. An apparatus for adjusting the position of materials during processing, comprising:

first and second material aligners each comprising:

a material contact loop comprising rollers distributed about a length of the material contact loop, the rollers configured to rotate about a rotational axis substantially parallel to the material contact loop;

a support arm comprising a plurality of loop guides, the material contact loop positioned over the plurality of loop guides; and;

a loop driver coupled to at least one loop guide of the plurality of loop guides, the loop driver configured to control rotation of the material contact loop about the plurality of loop guides and along a length of the support arm, while allowing rotation of the rollers about the rotational axis;

where the first and second material aligners are positioned with the length of the first material aligner substantially parallel with the length of the second material aligner, and the rollers along one side of the support arm of the first material aligner are adjacent to the rollers along one side of the support arm of the second material aligner opposite the first material aligner.

2. The apparatus of claim **1**, comprising a ply separator positioned between the one side of the first material aligner and the one side of the second material aligner.

3. The apparatus of claim **2**, wherein the ply separator comprises a first planar surface adjacent to the rollers along the one side of the first material aligner and a second planar surface adjacent to the rollers along the one side of the second material aligner.

4. The apparatus of claim **2**, wherein a length of the ply separator is substantially parallel with the lengths of the first and second material aligners.

5. The apparatus of claim **2**, wherein the first and second material aligners are offset from each other on opposite sides of the ply separator.

6. The apparatus of claim **2**, wherein the ply separator comprises a mounting support extending from one end of the ply separator.

7. The apparatus of claim **1**, wherein the material contact loop of the first material aligner is substantially parallel with the material contact loop of the second material aligner.

8. The apparatus of claim **7**, wherein the material contact loops of the first and second material aligners are positioned in a common plane.

9. The apparatus of claim **1**, wherein the material contact loop is a roller chain, and the rollers comprise rollers separated by spacers about the length of the circular roller chain.

10. The apparatus of claim **9**, wherein the rollers and spacers are secured in series to form the circular roller chain.

11. The apparatus of claim **10**, wherein the rollers and spacers are secured by a cable extending through the rotational axis of the rollers and through the spacers.

12. The apparatus of claim **1**, wherein the material contact loop comprises a belt, where the rollers are offset from and secured to the belt by a support structure.

13. The apparatus of claim **12**, wherein the support structure is detachably attached to the belt.

14. The apparatus of claim **12**, wherein a coating or contact layer is disposed on an outer surface of the rollers.

15. A system for transporting and sewing material, comprising:

a sewing or bonding machine configured to join pieces of material;

first and second material aligners each comprising:

a material contact loop comprising rollers distributed about a length of the material contact loop;

a support arm comprising a plurality of loop guides, the material contact loop positioned over the plurality of loop guides; and;

a loop driver coupled to at least one loop guide of the plurality of loop guides, the loop driver configured to control rotation of the material contact loop about the plurality of loop guides and along a length of the support arm;

where the first and second material aligners are positioned with the length of the first material aligner substantially parallel with the length of the second material aligner, and the rollers along one side of the support arm of the first material aligner are adjacent to the rollers along one side of the support arm of the second material aligner opposite the first material aligner; and

where rotation of the material contact loop about the support arm of the first material aligner repositions a first piece of material in contact with the rollers along the one side of the first material aligner and rotation of the material contact loop of the second material aligner repositions a second piece of material in contact with the rollers along the one side of the second material aligner.

16. The system of claim **15**, comprising a ply separator positioned between the one side of the first material aligner and the one side of the second material aligner, the first piece of material between the rollers along the one side of the support arm of the first material aligner and a first side of the ply separator and the second piece of material between the rollers along the one side of the support arm of the second material aligner and a second side of the ply separator.

17. The system of claim **15**, wherein rotation of the material contact loop of the first material aligner repositions the first piece of material along a length of the ply separator, and the rollers allow free movement of the material perpendicular to the length of the ply separator.

18. The system of claim **15**, wherein rotation of the material contact loop of the second material aligner repositions the second piece of material along a length of the ply separator, and the rollers allow free movement of the material perpendicular to the length of the ply separator.

19. The system of claim **15**, wherein the material contact loop is a circular roller chain, and the rollers comprise rollers separated by spacers about the length of the circular roller chain.

20. The system of claim **15**, wherein the material contact loop comprises a belt, where the rollers are offset from and secured to the belt by a support structure.

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